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FEDERAL RESEARCH RESOURCES: A PROCESS FOR SETTING PRIORITIES

FINAL REPORT

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NATIONAL SCIENCE BOARD

AD HOC COMMITTEE ON STRATEGIC SCIENCE AND ENGINEERING POLICY ISSUES

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EXECUTIVE SUMMARY

Federal Research Resources: A Process for Setting Priorities

CONTEXT AND FRAMEWORK FOR THE STUDY

The Federal government's policy for investment in science and technology over the last 50 years has yielded enormous benefits to the economy, national security, and quality of life in the U.S. The Federal share of total national science and technology investment is critically focused in areas that would be inadequately funded or not supported by the private sector. These include research to support Federal missions; research that is high-risk, requires long-term investment in the expectation of future high payoffs to society; unique, costly, cutting-edge research facilities and instruments; and academic research that, as a primary purpose, supports the education of the future science and engineering workforce.

> *Our challenge, now and in the future, will be to maintain a steady flow of understanding-driven scientific and engineering studies even in the face of limited federal resources. Meeting this challenge means that priorities for spending on science and engineering by the federal government will have to be set.*
>
> U. S. House of Representatives, *Unlocking Our Future*

Over $90 billion[1] was allocated to Federal R&D in the most recent budget--representing a little more than a quarter of all national R&D. With such a large investment of public funds, policy makers in Congress and the Executive branch are asking for convincing evidence of the effectiveness of Federal investments in the form of hard data on benefits. There is general recognition among policy makers that outstanding opportunities for excellent research far exceed any reasonable level of funding by the Federal government. Choices must be made. Wise, well-informed choices among alternatives will sustain a strong, balanced research infrastructure to enable the discoveries that will be a foundation for future prosperity.

The current system for priority setting in the Federal research budget lacks a coherent, scientifically based process for systematic review and evaluation of the broad Federal investment portfolio for effectiveness in achieving national goals. Moreover available data and analyses are often ill suited for informing budget allocation decisions that affect U.S. research infrastructure.

[1] Office of Management and Budget, "Analytical Perspectives," *Fiscal Year 2002 Budget of the United States Government*, Table 7-2, Research and Development Spending.

Decision makers must rely on the scientific community to provide the best advice on the most promising research investment choices for the future. The form and timing of such advice is also important. Appropriate advice must include a reasonable estimate of the level of funding that would be required for adequate support of a new initiative over time, provide tradeoff options to enable funding for priorities, and must be available on a schedule compatible with the Federal budget process.

No process now exists for weighing the available evidence on competing research investment opportunities across broad fields of research. It is critical that the choices among such opportunities be based on a process that is transparent and credible with the scientific communities and the general public and its representatives. Such a function requires an organizational home, appropriate expert resources, and adequate financial support.

Since the mid 1990s, the National Science Board has been actively engaged in issues of priority setting for the Federal research portfolio.[2] In 1999, the Board charged its Ad Hoc Committee on Strategic Science and Engineering Policy Issues to undertake a study of research budget coordination and priority setting methodologies across fields of science and engineering in the U.S. and in other countries.

CONDUCT OF THE STUDY

The study, *Federal Research Resources: A Process for Setting Priorities* (NSB 01-156), which follows on recommendations of the Board's previous working paper on *Government Funding of Scientific Research* [NSB 97-186), responds to a request by the House Appropriations Committee[3] and the encouragement of the Office of Management and Budget. In its February 1999 *Strategic Plan* the Board identified this effort as a high priority for national science policy.

> *Science and technology are critically important to keeping our nation's economy competitive and for addressing challenges we face in health care, defense, energy production and use, and the environment. As a result, every federal research and development (R&D) dollar must be invested as effectively as possible.*
>
> OMB, *The President's Management Agenda, Fiscal Year 2002*

The Committee on Strategic Science and Engineering Policy Issues commissioned reviews of the literature in two areas.[4] The first focused on Federal research budget coordination, priority setting across fields of science and engineering, and available data and analytical tools to support priority setting. A second study of the same subject reviewed international models of S&T budget coordination and

[2]In Support of Basic Research--NSB 93-127; Federal Investments in Science and Engineering--NSB 95-254 and Statement on Federal R&D Budget Realignment--NSB 95-26, were issued from 1993 to 1995, in addition to more recent papers.

[3] Report 105-610, 105th Congress, 2nd Session, House of Representatives. To accompany H.R. 4194.

[4] Steven W. Popper, Caroline S. Wagner, Donna L. Fossum, William S. Stiles. *Setting Priorities and Coordinating Federal R&D Across Fields of Science: A Literature Review* (DRU-2286-NSF). Washington DC: RAND Science and Technology Policy Institute, April 2000; and H. Roberts Coward. *Final Report: Symposium on International Models and Budget Coordination and Priority Setting for S&T.* Washington DC: SRI International, August 2000.

priority setting. It also included a symposium with presentations by S&T officials from eight foreign governments.

In addition to these studies, the Committee heard presentations by invited experts who discussed a wide range of methodologies and data to support budget allocation decisions for research. It also received written comments on its draft recommendations by mail and through the National Science Board website, and heard presentations broadly representative of stakeholders in Federal research. Stakeholder input culminated with a Symposium on May 21-22, 2001 on the Board's preliminary findings and recommendations, with more than 200 participants.

PRINCIPAL FINDINGS

- Federal priority setting for research occurs at three levels: 1) establishing Federal goals for research, 2) the budget allocation processes for research within the White House and Congress that in the aggregate produce the Federal research portfolio and 3) Federal agencies and departments in achieving their missions in accord with the President's priorities for research. This report focuses on the second level, that is, the White House and Congressional processes that in the aggregate produce the Federal portfolio of investments in research.

- The allocation of funds to national research goals is ultimately a political process that should be informed by the best scientific advice and data available.

- A strengthened process for research allocation decisions is needed. Such allocations are based now primarily on faith in future payoffs justified by past success. They are difficult to defend against alternative claims on the budget that promise concrete, more easily measured results and are supported by large and vocal constituencies.

- The pluralistic framework for Federal research is a positive aspect of the system and increases possibilities for funding high-risk, high-payoff research. An improved process for budget coordination and priority setting should build on strengths of the current system and address weaknesses in data, analyses, and expert advice.

- There is a need for regular evaluation of Federal investments as a portfolio for success in achieving Federal goals for research, to identify areas of weakness in national infrastructure for S&T, and to identify a well-defined set of the top priorities for major new research investments.

- Additional resources are needed to provide both Congress and the Executive branch with data, analyses, and expert advice to inform their decisions on budget allocations for research.

RECOMMENDATIONS

Implementation of a broad-based, continuous capability for expert advice to both OMB and Congress during the budget process would yield immediate benefits to decision makers. There is also a long-term need for a regular, systematic evaluation of the effectiveness of Federal investments in achieving Federal goals for research through the Office of Science and Technology Policy, drawing broad-based input from scientific experts and organizations in all sectors. Complementing both would be improved analyses on research opportunities, needs, and benefits to society; and timely data that trace Federal research investments through the budget process and beyond.

KEYSTONE RECOMMENDATION 1

The Federal government, including the White House, Federal departments and agencies, and the Congress should cooperate in developing and supporting a more productive process for allocating and coordinating Federal research funding. The process must place a priority on investments in areas that advance important national goals, identify areas ready to benefit from greater investment, address long-term needs and opportunities for Federal missions and responsibilities, and ensure world class fundamental science and engineering capabilities across the frontiers of knowledge. It should incorporate input from the Federal departments and agencies, advisory mechanisms of the National Academies, scientific community organizations representing all sectors, and a global perspective on opportunities and needs for U.S. science and technology.

Research Community Input on Needs and Opportunities:

Presently there is no widely accepted and broadly applied way for the Federal government to obtain systematic input from the science and engineering communities to inform budget choices on support for research and research infrastructure. The current system often fails to produce advice and information on a schedule useful to the budget process and responsive to needs for broad-based, informed assessments of the benefits and costs of alternative proposals for Federal support. A more effective system for managing the Federal research portfolio requires adequate funding, staffing and organizational continuity.

RECOMMENDATION 2

A process should be implemented that identifies priority needs and opportunities for research--encompassing all major areas of science and engineering--to inform Federal budget decisions. The process should include an evaluation of the current Federal portfolio for research in light of national goals, and draw on: systematic, independent expert advice from the external scientific communities; studies of the costs and benefits of

research investments; and analyses of available data; and should include S&T priorities, advice, and analyses from Federal departments and agencies. The priorities identified would inform OMB in developing its guidance to Federal departments and agencies for the President's budget submission, and the Congress in the budget development and appropriations processes.

Executive Branch Advisory Mechanism:

The Executive branch should implement a more robust advisory mechanism, expanding on and enhancing current White House mechanisms for S&T budget coordination and priority setting in OSTP and OMB. It is particularly essential that the advisory mechanism include participants who are experienced in making choices among excellent opportunities or needs for research, for example, vice provosts for research in universities, active researchers with breadth of vision, and managers of major industrial research programs.

RECOMMENDATION 2a

An Executive branch process for ongoing evaluation of outcomes of the Federal portfolio for research in light of Federal goals for S&T should be implemented on a five-year cycle[5]. A report to the President and Congress should be prepared including a well-defined set of the highest long-term priorities for Federal research investments. These priorities should include new national initiatives, unique and paradigm shifting instrumentation and facilities, unintended and unanticipated shifts in support among areas of research resulting in gaps in support to important research domains, and emerging fields. The report should also include potential trade-offs to provide greater funding for priority activities. The report should be updated on an annual basis as part of the budget process, and should employ the best available data and analyses as well as expert input. Resources available to OSTP, OMB and PCAST should be bolstered to support this function.

Congressional Advisory Mechanism:

There is no coherent congressional mechanism for considering allocation decisions for research within the framework of the broad Federal research portfolio. Though improvements in the White House process––particularly expansion of activities and resources available to OSTP––would benefit congressional allocation decisions, one or more congressional mechanisms to provide expert input to research allocation decisions are badly needed.

[5] The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the scale of the effort, which would require a longer time than an annual process, and the increasingly rapid changes in science that demand a frequent reevaluation of needs and opportunities for investments.

RECOMMENDATION 2b

Congress should develop appropriate mechanisms to provide it with independent expert S&T review, evaluation, and advice. These mechanisms should build on existing resources for budget and scientific analysis, such as the Congressional Budget Office, the Congressional Research Service, the Government Accounting Office, and the National Academies. A framework for considering the full Federal portfolio for science and technology might include hearings by the Budget Committees of both houses of Congress, or other such broadly based congressional forums.

Definitions, Data and Data Systems:

High quality data and data systems to monitor Federal investments in research would enhance the decision process. Such systems must be based on definitions of research activities that are consistently applied across departments and agencies and measured to capture the changing character of research and research needs. Improving data will require long-term commitment with input from potential users and contributors, and appropriate financial support.

RECOMMENDATION 3

A strategy for addressing data needs should be developed. Such a strategy supported by OMB and Congress and managed through OSTP and OMB would assure commitment by departments, agencies and programs to timely, accessible data that are reliable across reporting units and relevant to the needs for monitoring and evaluating Federal investments in research. Current data and data systems tracking federally funded research should be evaluated for utility to the research budget allocation process and employed as appropriate.

International Comparisons:

Both relative and absolute international statistical data and assessments should be a major component of the information base to support Executive Branch and Congressional research budget allocation decisions. International benchmarking of U.S. research performance and capabilities on a regular basis responds to the growing globalization of science and technology and the need for the U.S. to maintain a world-class science and engineering infrastructure.

RECOMMENDATION 4

Input to Federal allocation decisions should include comparisons of U.S. research resources and performance with those of other countries. National resources and performance should be benchmarked to evaluate the health and vigor of U.S. science and engineering for a range of macroeconomic indicators, using both absolute and relative measures, the latter to control in part for the difference in size and composition of economies. Over the long term, data sources should be expanded and quality improved.

Federal Research Benefits to the Economy and Society:

In addition to monitoring Federal expenditures for research, measuring the benefits to the public of funded research is essential for prudent management. Implementation of this recommendation should be coordinated with Recommendation 3 on definitions and data systems.

RECOMMENDATION 5

The Federal government should invest in the research necessary to build deep understanding and the intellectual infrastructure to analyze substantive effects on the economy and quality of life of Federal support for science and technology. The research should include improvements to methods for measuring returns on public investments in research.

CONCLUSION

The Board's recommendations provide a framework for improving the quality, content, and accessibility of science and engineering expert advice, data, and analyses to inform decisions on priorities in the White House and Congress for Federal investments across fields of research. We are aware that implementing these recommendations will be difficult and require long-term commitment and support. In the interest of science and the Nation, we urge that the Federal government and its partners in the research community embrace this difficult task.

I. INTRODUCTION

In the fifty years since the end of World War II and the establishment of a national policy for Government support of scientific research in colleges and universities,[6] historical trends and events have changed the public expectations for Federal research investments. The most important historical event affecting the national post-World War II consensus on Federal participation in science and technology is the end of the Cold War. Until that time, the rationale for Federal investments in research relied heavily on the contributions of science and technology (S&T) to a strong national defense.

Box 1

"*Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific technological elite. It is the task of statemanship to mold, to balance, and to integrate these and other forces, new and old, within the principles of our democratic system—ever aiming toward the supreme goals of our free society."*

President Dwight D. Eisenhower, Farewell Address, 1/17/61

The last few Federal budget years have been favorable to research, but a favorable budget in one or two fiscal years does not obviate the need for a coherent post-Cold War Federal policy and decision process to guide investment in S&T. It is difficult to envision a reversal of the tide of accelerating competition among exploding scientific opportunities and between science and other worthy claimants on the budget. Today's environment demands more effective management of the Federal portfolio for research, including a sustained advisory process that incorporates systematic involvement of participants in the U.S. research enterprise, including the science and engineering communities, Federal agencies that fund research, industry, nonprofit organizations that fund and perform research, and, increasingly, state governments. Expert input is particularly important for decisions on long-term, high-risk investments in research–-sponsored mainly by the Federal government-–which are steadily losing ground in the national research portfolio to short-term investments.

The Federal commitment to research over the last half-century has contributed to a continuous outpouring of benefits to the public from advances in science and technology. Furthermore, within the last few decades these benefits have become increasingly visible and pervasive, from economic growth driven by high technology industries, to science and technology based transformations in many areas of public and private life—including, among others, the revolution in communications and information technologies, major medical breakthroughs, and superior defense technology demonstrated in the field. These transformations underscore the value of sustained public investments reaching back decades. Moreover, even as the Federal share of funding has declined in national research and development (R&D), non-

[6] Vannevar Bush, *Science--The Endless Frontier*.

Federal sectors of the economy—industry, academe, state and non-profit—have come to rely on the Federal Government to play a critical role in funding long-term investments in science and engineering discovery, education and innovation.

The success of the U.S. in encouraging the growth of its high technology industrial sector through public funding for science and engineering research and advanced education led to the U.S. system becoming a widely emulated international model. As Federal Reserve Chairman Alan Greenspan[7] noted: " . . . the research facilities of our universities are envied throughout the world . . . The payoffs in terms of the flow of expertise, new products, and start-up companies, have been impressive." Nonetheless, recognition of the benefits of past public investments does not guarantee public support of the science and technology infrastructure necessary to enable future discoveries that may not yield measurable benefits for decades. Critics and supporters alike note the need for a clearly articulated and compelling rationale for Federal investments in science and technology equivalent in persuasive powers to the rationale of the Cold War.

US R&D/GDP: 1953-2000

FIGURE 1 UNAVAILABLE

Figure 1: Since the 1960s, national expenditures for R&D have been in the range of 2 to 3 percent of GDP

[7]Remarks by Chairman Alan Greenspan "Structural change in the new economy," before the National Governors' Association, 92nd Annual Meeting, State College, Pennsylvania July 11, 2000.

II. NATIONAL POLICY CONCERNS AND NEEDS

Decision makers in the Executive and Legislative branches of government are concerned about the management of Federal investments in research, which in the most recent budget had reached more than $90 billion for R&D.[8] Articulating this concern, former Office of Management and Budget (OMB) Director Franklin Raines[9] raised the following questions: How large a scientific enterprise does the United States need? How can we set priorities in the Nation's R&D enterprise? How can we measure the success of our Nation's research programs? How can we strengthen the government-university partnership? How do we engage the American people in the excitement and wonder of science?

Likewise, Chairman of the House Science Committee, Sherwood Boehlert,[10] responded to the proposal to double Federal funding for research by questioning: "What are we going to get for that money? How will we know if we are under- or over-spending in any field?" He went on to warn: "I want the Committee, early on, to take a serious look at the balance within the federal research portfolio . . . You can . . . count on me to ask tough and uncomfortable questions to ensure that the scientific community is acting in its and the nation's long term interest . . . We really need to push for more data". (1/21/2001).

How should the scientific community respond to these questions and expectations? How should it raise public awareness that the quality of life in the future will depend in large measure on the generation of new wealth, on safeguarding human health and the health of our planet, and on opportunities for enlightenment and individual development made possible by science and engineering discoveries? Will the response of the scientific community be effective against competing claims on the Federal budget?

Shares of National R&D Funding by Source: 1953-2000

FIGURE 2 UNAVAILABLE

Figure 2: Since 1980 Industry has become increasingly dominant in national R&D

[8] Office of Management and Budget, Fiscal Year 2002 Budget of the United States Government, Table 7-2, Special Analyses.
[9] Franklin D. Raines. "Making the Case for Federal Support of R&D," *Science,* 12 June 1998, 1671.
[10] Congressman Sherwood Boehlert (R-NY) Speech To Universities Research Association January 31, 2001.

These issues have prompted a vigorous policy debate over the last decade involving the Executive and the Legislature, the National Academies, and professional societies. Nonetheless, the debate to this point has generated no widely accepted process for the Federal Government, with systematic input from the scientific community and its representatives in all sectors of the economy, to make priority decisions about the allocations in and across fields of research in support of Federal goals.

The National Science Board (the Board) has participated in this debate, issuing a series of policy statements, including an NSB working paper on *Government Funding of Scientific Research* in 1997. The Board concluded in that paper that within the Federal budget there should be an overall strategy for research, with areas of increased and decreased emphasis and a level of funding adequate both to serve national priorities and to foster a world-class scientific and technical enterprise. To this end Congress and the Administration need to establish a process that examines the Federal research budget before the total Federal budget is disaggregated for consideration by congressional committees. The Board further concluded in its 1998 *Strategic Plan* that a prerequisite for a coherent and comprehensive Federal allocation process for research is the development of an intellectually well-founded and broadly accepted methodology for setting priorities across fields of science and engineering.

As follow-up to its earlier work, the Board undertook, beginning in March 1999, a focused examination of Federal priority-setting methodologies for research in the United States at three levels: 1) setting Federal goals, 2) allocation decisions by Congress and the Administration that produce the Federal portfolio for research and 3) Federal agencies and departments in achieving their missions in alignment with stated Federal priorities. The Board determined that the appropriate level for its focus is the second level, that is, the White House and congressional processes that in the aggregate produce the Federal portfolio of investments in research.

Context for Federally Funded Research

The Federal role has always encompassed the missions of Federal agencies and departments and, beyond those missions, has helped to sustain a healthy national infrastructure for S&T. The Federal role today is especially critical for research that is high risk, requires long-term investment in the expectation of future high payoffs to society or that is unlikely to be funded by the private sector; for unique, costly, cutting edge research facilities and instrumentation; and for academic research that, as a primary purpose, supports the education of the future science and engineering workforce. It is this portion of the Federal research portfolio that is especially vulnerable to diversion of funds to areas of research with more clear and immediate payoffs to society or to other important goals of Federal mission departments and agencies. It is also the critical Federal investment in our Nation's future science and technology capabilities.

BOX 2

"I doubt that anyone would sign on to a research project as poorly designed as our current national experiments in science and technology policy . . . our scientific enterprise remains adrift, without a connection to the broader society." –Representative George E. Brown, Jr., 1998

PROCESS FOR PRODUCING THE REPORT

The study responds to the House Committee on Appropriations FY 1999 report urging the Board to undertake the study and the encouragement from Office of Management and Budget (OMB) for this effort. The Board Ad Hoc Committee on Strategic Science and Engineering Policy Issues was charged to examine the state of the art in budget coordination and priority setting for research across fields of science and engineering in the U.S. and internationally, and to convene appropriate stakeholders to consider the findings of these studies and reviews, to develop recommendations for improved methodologies for coordination and priority setting of the Federal research budget and for building the support of the science and engineering communities for these methodologies. The study included two literature reviews:

- Federal research budget coordination and priority setting
- International models of science and technology budget coordination and priority setting.

The Committee heard presentations by invited experts, addressing the following methodologies and topics:

- International models for S&T budget coordination and priority setting; a one-and- a- half day Symposium was held in November, 1999, opened by the U.S. Presidential Science Advisor, with presentations by foreign officials for eight governments: the United Kingdom, Germany, France, Sweden, the Republic of Korea, Japan, Brazil, and the European Union;
- A project to develop a more complete and accessible database for tracking Federal R&D funding, the RaDiUS database, and data issues in tracking S&T activities in the Federal budget;
- Foresight methods, used by many countries as part of the dialogue toward establishing priorities for S&T;
- The Federal Science and Technology (FS&T) budget analysis by the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academies and the American Association for the Advancements of Science;
- Experiments in international benchmarking of U.S. research fields--undertaken by COSEPUP;
- Approaches to priority setting-for research in the academic sector, and the relationship between Federal and academic priority setting;
- Priority-setting practices in industry, and the role of industry and the Federal government in national R&D;
- Economic methods to measure the benefits of Federal investments in research and to inform budget allocation decisions; presented by academic experts on economic methods to measure returns on research investments; and experts on the Federal budget from the Congressional Budget Office and Council of Economic Advisors.

The study included an overview of budget coordination and priority setting in Federal S&T agencies in a meeting with representatives of the Office of Science and Technology Policy, Office of Management and Budget, Department of Energy, National Institutes of Health, National Science Foundation, National Aeronautics and Space Administration, U.S. Department of Agriculture, Environmental Protection Agency, National Oceanographic and Atmospheric Administration, Department of Defense, Veterans Health Administration, National Institute of Science and Technology August 3-4, 2000, and a discussion with House Appropriations staff.

Finally, the Committee sponsored a stakeholders' symposium on Allocation of Federal Resources for Science and Technology, May 21-22, 2001, focused on the Board-approved discussion document, *The Scientific Allocation of Scientific Resources* (NSB 01-039), containing preliminary recommendations. The report and invitation to the symposium were distributed by webpage, email and mail to members of the stakeholder communities. The symposium included 20 speakers and panelists and encouraged active audience participation. It was attended by more than 200 members of the stakeholder community including representatives from Congressional staff, science policy organizations, Federal agencies, academic organizations, scientific community organizations, science media, industry representatives and interested individuals.

The national science and technology enterprise has grown and become more pervasive in both the private sector and in government, even as the Federal share of support to the enterprise has declined. Now, more than ever, achieving Federal goals for sustaining U.S. leadership in S&T demands partnerships and cooperation with other sectors. Understanding where Federal funding can be best employed and the level of investment required to assure the health of U.S. science and technology is essential to prudent management of the Federal portfolio. Commitment to an intellectually well-founded, long-term strategy for Federal research must be an integral aspect of a sound fiscal policy, regardless of year-to-year fluctuations in available funds. The Federal budget process for research must assure sustained and sufficient support for a diverse, flexible, opportunistic portfolio of investments, emphasizing the long-term health of the knowledge base and infrastructure for research—including human resources.

Need for A Different Approach to Budget Coordination and Priority Setting

The Board's discussions with spokespersons from Executive and Legislative branches and with experts on the budget, data and analytic methods, as well as reviews of the literature on budget coordination and priority setting, identified the following needs.

Methodologies for:

- Determining the appropriate size of the enterprise
- Determining the appropriate level of support to individual fields
- Achieving balance in the portfolio
- Setting priorities for the Nation's research enterprise
- Achieving effective communication on scientific matters with the American people
- Strengthening government partnerships and collaboration in research with other sectors and other international partners

Improved data, expert analyses, and scientific advice include:

- A continuing mechanism for expert advice representing a broad cross-section of the science and engineering research and education community to support difficult decisions on research investments—especially in major infrastructure projects
- Better quantitative data and methods of analysis adequate to measure the benefits of research
- A mechanism to identify and track the relevant Federal funds for S&T through the budget process in the Administration and Congress

The Current Federal System

The current Federal system for allocating funds for research is an incremental process that results in final allocation decisions based on input from a range of stakeholders,

including the science and engineering communities. Ultimately, the Federal budget for research rests on aggregated political decisions in thirteen congressional appropriations subcommittees. There has been a host of critiques and suggestions for improving the process, many focused on the goals for research, but some suggesting changes to the process itself. The most frequent critique addresses a perceived lack of a clear methodology for priority setting and coordination. Several possible remedies have been suggested: structural changes to the process, alternative interpretations of the appropriate goals for Federal research, and new mechanisms for funding allocations and better management of the Federal research portfolio.

Since the late 1980s, and under both Republican and Democratic administrations, there has been substantial attention devoted to developing better mechanisms for coordinating the Federal budget for research through OMB and the Office of Science and Technology Policy (OSTP) (Box 3).

Box 3. WHITE HOUSE S&T POLICY APPARATUS

Office of Science and Technology Policy (OSTP): The legislation that established OSTP declares that the United States shall adhere to a national policy for science and technology which includes the following principles: (1) the continuing development and implementation of a national strategy for determining and achieving the appropriate scope, level, direction, and extent of scientific and technological efforts based upon a continuous appraisal of the role of science and technology in achieving goals and formulating policies of the United States; (2) the enlistment of science and technology to foster a healthy economy in which the directions of growth and innovation are compatible with the prudent and frugal use of resources and with the preservation of a benign environment; and (3) the development and maintenance of a solid base for science and technology in the United States. It states the declaration of Congress that the Federal Government should maintain central policy-planning elements in the executive branch in mobilizing resources for essential science and technology programs, in securing appropriate funding for those programs, and to review systematically Federal science policy and programs and to recommend legislative amendments when needed. The functions of the Office include: (1) advise the President of scientific and technological considerations involved in areas of national concern; (2) evaluate the scale, quality, and effectiveness of the Federal effort in science and technology and advise on appropriate actions; (3) advise the President on scientific and technological considerations with regard to Federal budgets; and (4) assist the President in providing general leadership and coordination of the research and development programs of the Federal Government. (Excerpted from Public Law 94-292)

National Science And Technology Council (NSTC): The NSTC functions were to: 1) coordinate the science and technology policy-making process; 2) ensure science and technology policy decisions and programs are consistent with the President's stated goals; 3) help integrate the President's S&T policy agenda across the Federal Government; 4) ensure S&T are considered in development and implementation of Federal policies and programs; and 5) further international cooperation in science and technology (Executive Order 12881, November 23, 1993, Section 4).

Federal Coordinating Council for Science, Engineering and Technology (FCCSET): Established in 1976 under OSTP in the National Science and Technology Policy, Organization, and Priorities Act, FCCSET was "to consider problems and developments in fields of science, engineering, and technology and related activities affecting more than one Federal agency, and to recommend policies designed to provide more effective planning and administration of Federal scientific, engineering, and technological programs." (Title IV, Public Law 94-292).

The cabinet-level National Science and Technology Council (NSTC) (Box 3) in the previous Administration and the earlier Federal Coordinating Council for Science, Engineering and Technology (FCCSET) provided mechanisms in OSTP for identifying major national initiatives that cut across agencies in designated priority areas (e.g., nanotechnology, global climate change, and information technology). Under the last Administration, the NSTC was established by Executive order as part of the OSTP science and technology policy apparatus. However, unlike FCCSET, OSTP and the Director of OSTP, which were established through legislation, the NSTC had no permanent status. Likewise, the President's Committee of Advisors on Science and Technology (PCAST), whose purpose was to provide "critical links to industry and academia," was established by Executive order. (See Box 3).

Furthermore, in neither the Executive nor the Legislative branches is there a mechanism for evaluation that takes into account the breadth of Federal investments within the context of Federal goals for research. The Executive branch, through OMB, OSTP and PCAST, made an effort to treat Federal funding of research as a portfolio, recently taking into account the issue of balance among fields of science in Federal support across all agencies and departments.

These steps have been in the right direction but are only a preliminary effort. Congress also has directed attention to what might be done to improve its process but has not yet taken any action to implement formal mechanisms comparable to OSTP to coordinate functions across budget lines, agencies and departments, and committees. (See Box 6).

"The Federal role today is especially critical for research that is high risk, requires long-term investment in the expectation of future high payoffs to society or that is unlikely to be funded by the private sector; for unique, costly, cutting edge research facilities and instrumentation; and for academic research that, as a primary purpose, supports the education of the future science and engineering workforce."

Budget Coordination and Evaluation of the Portfolio

To enhance the effectiveness of Federal investments in achieving long-term goals for research, a regular, credible process that relies in part on expert input from the science and engineering communities is essential for priority setting among competing investment choices. The Federal portfolio for research is an aggregate of the research portfolios of the individual departments and agencies funding S&T. It has not been managed as a portfolio. As a precondition for priority setting across the Federal research budget, coordination must be achieved among its diverse components. While efforts at better coordination through OSTP mechanisms have been useful in managing cross-agency initiatives, coordinating mechanisms are also necessary for evaluating the performance of Federal research investments as a portfolio and for identifying gaps, overlaps, areas for decreased emphasis, and the top priorities for additional investments. Coordination and priority setting therefore must be intertwined in the Federal research budget process.

The Need for More and Credible Data and Analyses

No mechanism exists to provide strong quantitative input to justify a particular level of investment in Federal research based on expected benefits to society, due in part to the lack of data and methods to measure research benefits. Data on Federal research funding, especially at the field level, are often unavailable on a timely basis to inform budget allocation decisions, use outdated research field definitions, fail to capture important characteristics of research activities—particularly growing collaboration across fields, organizations, sectors, and even nations--and suffer from inconsistent applications of definitions across reporting units.

Box 4. COORDINATING THE BUDGET FOR S&T IN CONGRESS

At no time in the congressional authorization or appropriations process is the research portfolio examined as a whole, across the Federal government. The consideration of segments of the research budget in a large number of committees and subcommittees makes it impossible for Congress to consider the impacts of individual funding decisions on the U.S. science and technology capabilities. The House Science Policy Study, *Unlocking Our Future*, argues that:

> *. . . at a minimum Congress and the Executive Branch should improve their internal coordination processes to more effectively manage, execute, and integrate oversight . . . While the Office of Management and Budget can fill this role in the Executive Branch, no such mechanism exists in the Congress. In those cases where two or more Congressional committees have joint jurisdiction over or significant interest in large, complex technical programs, the affected committees should take steps to better coordinate their efforts. Wherever possible, the affected committees should consider holding joint hearings and perhaps even writing joint authorization bills.*

In spite of the need for more and better data on the Federal research enterprise, collecting such data requires consistent cooperation of a large number of Federal agencies and departments. There are few resources available to address the major undertaking that would be required to generate reliable data tailored to the needs of budget decisions and outcomes for research funding allocations.

It would require a concerted effort to define and obtain agreement among the many Federal units that would be involved, and would require support from OMB and Congress to assure collection of high quality, timely data tailored to tracking the Federal funding for science and technology through the budget process and beyond. Nonetheless, National Science Foundation and other major research funding agencies have been open to developing consistent and appropriate data tools for managing the Federal research portfolio and for communicating with more credibility to the public concerning their investments in research and education.

Identifying the Composition of the Federal Research Portfolio

OMB requires agencies to report R&D activities that they are funding for the annual budget process. Even if reliably measured across funding units, since "D" (development) at about 55 percent of the total is larger than "R" (research), reporting the sum of the two as the measure of Federal research investment results in an indicator that fails to reflect accurately the Federal funding to discovery and innovation. Also, significant fluctuations in support for "R" tend to be obscured when combined with the larger "D" category funds.

Box 5.

"The nation must reach a common ground and define a more realistic, pragmatic framework for allocating federal R&D resources. Only an inclusive national dialogue that brings together both the executive and legislative branches of government with the private sector and the U.S. university community will produce the needed consensus." --Council on Competitiveness, *Endless Frontier, Limited Resources, 1996*

There have been several attempts to provide a better measure for the federally funded activities that contribute to national innovation. The National Academies proposed a coordinated "Federal Science and Technology Budget"[11], a subset of Federal R&D that constitutes "federal support for a national science and technology base." The FS&T budget would provide Congress with a tool for tracking the aggregated pool of Federal departmental and agency funds that support the science and technology base. OMB has employed over the last few budget cycles[12] a similar mechanism for tracking the President's research priorities through the budget process. This mechanism comprised a collection of program budgets that are primarily research programs but also includes non-research elements, such as the education and human resources component of the budget for NSF. OMB found this mechanism useful in highlighting Federal research investments and effective in supporting the President's priorities for research through the budget cycle.

The Board, for the purposes of this study, has focused on S&T. In so doing, the Board follows the approach of organizations such as the National Research Council and OMB, which identify basic and applied research activities for tracking through the budget process. At the same time the Board recognizes that S&T has been defined in a variety of ways in the Federal portfolio, and that as yet there is no consensus on federally funded activities that should constitute Federal S&T. Criteria for inclusion of activities in a Federal budget for research for the purpose of monitoring and evaluating Federal activities as a portfolio will require further discussion and analysis.

The important subset of research funding devoted to the long-term, high-risk basic research is especially vulnerable to becoming invisible in the larger budget for S&T. It is critical that this component receive sustained public support to produce as yet unforeseen major breakthroughs in knowledge and, when performed in academic

[11] National Research Council, Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology*.
[12] Office of Management and Budget, Table 7-3.

institutions, to provide opportunities for experience in cutting-edge research for advanced science and engineering students under the guidance of faculty mentors.

Capturing the Character of Activities Supported at the Field Level

Within research, the character of research fields and activities has changed over time, resulting in definitions that no longer capture important distinctions in federally funded research activities. Special areas of weakness include multidisciplinary and cross-disciplinary workgroups and teams, emerging areas, differences in interpretation across agencies' reporting units, and the evolving content of traditional research fields themselves. In addition, educational contributions of research--particularly in academic institutions for graduate education—are not captured in most agencies' databases. Current field-level data have the advantage of providing a time series to reveal trends in support to fields of science and engineering. New information technology is available to support development of richer, more easily accessible and more flexible databases for federally funded research activities.

FIGURE 3
UNAVAILABLE

Over the last three decades the Life Sciences have come to dominate the Federal portfolio of research investments

Reliability and Timeliness

Differences in interpretation have resulted in wide discrepancies in research funding reported by performing and funding units—or even within the Federal Government across agencies and programs—even though they ostensibly describe the same activities. In addition, timeliness, in most cases essential to budget allocation decisions, is not possible with Federal databases based on surveys. Much of the data measuring the Federal research portfolio with respect to programs funded, support for fields of science and engineering, and performing institutions are several years old at best. Timeliness will become increasingly more problematic as rapid changes in science and technology increase the need for current data to monitor Federal investments. Agencies and departments could benefit from coordinated efforts across S&T funding units to develop a more efficient and timely data collection process while assuring the integrity of the data they provide.

Box 6. SCIENCE AND TECHNOLOGY ADVICE TO CONGRESS

Congressional mechanisms that could provide review, assessment, and advice on science and technology issues in the past included:

- The Congressional Budget Office (CBO), established under the Congressional Budget Impoundment and Control Act in 1974 (PL 92-599) to provide objective, nonpartisan assistance to legislators, scores the costs of bills and prepares budget and economic forecasts;
- The Congressional Research Service (CRS) provides Congress with quick responses to a large number of requests for reports. CRS recently merged its Science, Technology and Medicine Division into two other divisions: Resources, Science and Industry (RSI) and Domestic Social Policy (DSP);
- The General Accounting Office (GAO) was established as auditor for Congress in 1921, but in the 1970s won broad authority to audit Federal programs; it was subjected to a 25 percent budget reduction in the mid 1990's. The GAO Energy Resources and Sciences Issue Area was reorganized into the Natural Resources and Environment Team in October 2000 as part of a general reorganization;
- The Office of Technology Assessment (OTA) was established by legislation in 1972 (PL 92-484) to provide Congress with "early indications of the probable beneficial and adverse impacts of the applications of technology and to develop other coordinate information which may assist Congress. " In total, it prepared about 700 reports over 23 years.

Several of the Congressional support agencies were affected by Congressional budget cuts in the mid 1990s, with all funding eliminated for OTA in 1995.

Other mechanisms legislatively required to provide science and technology support to Federal policymakers, including Congress, are:

- The National Academies, including the Academies of Science and Engineering, the Institute of Medicine, and the National Research Council;
- The National Science Board;
- The Office of Science and Technology Policy.

Congress also employs hearings to obtain expert testimony on science and technology concerns.

Although the need to provide Congress with more systematic S&T review, assessment and advice has been widely supported in concept, opinions vary on appropriate mechanisms to accomplish this end.

Assessing World Leadership of U.S. Science and Engineering

National capabilities in science and technology and the government role in enhancing these assets are a growing emphasis for governments around the world. As science and technology capabilities have become more broadly distributed, there is a need for the United States to monitor the U.S. enterprise against an international backdrop to detect declines in national capabilities in science and technology relative to other nations or to identify new opportunities for research investment that merit public support. The National Academies have urged regular international benchmarking at the field level to assess the health of individual fields of research in the United States.[13] The use of international comparisons of the productivity of research fields and international expert participation in assessments of research programs are common in other countries. The Board has noted the need for monitoring the relative health of U.S. science and technology as part of a continuing evaluation of the Federal portfolio, drawing on existing data and expert analyses, and continually improving data and methods for international comparisons that inform priority setting.

Understanding the Role of Federal Research in Producing Economic and Other Benefits

A large number of studies have attempted to elucidate, and in many cases measure quantitatively, the relationship between research and innovation and the benefits of research for society. Organizations like the Council on Competitiveness, the Science and Technology Policy Institute, RAND; OSTP; and NSF have explored issues and methods for analyzing the role of a range of factors in innovation—including Federally funded research—and resulting economic and social benefits. On the other hand, academic programs are not doing enough to address these questions and are inadequately funded. The development of deeper understanding of the benefits from Federal research is an area where additional investment could improve both qualitative and quantitative data to inform budget allocation decisions, communicate the benefits of research to the public, and contribute to the effectiveness of Federal research investments.

Box 7.

"In the long run—in good budget years as in bad—it is essential that policymakers...recognize the fragility of (the U.S. S&T) enterprise and the critical federal role in sustaining it. It is up to the members of the science and engineering community to carry this message to them" – A.H. Teich, AAAS, 1999

[13]The National Academies, Committee on Science, Engineering and Public Policy. *Science, Technology and the Federal Government/National Goals for a New Era*, 1993 and National Research Council Committee on Criteria for Federal Support of Research and Development.

III. MAJOR FINDINGS AND ISSUES

The Board's findings are based on an intensive two-year study including review of the literature on Federal budget coordination and priority setting for science and engineering research, invited presentations from and discussions with representatives of OMB, OSTP, the Federal R&D agencies, Congressional staff, high level science officials from eight foreign governments, experts on data and methodologies, and industry, the National Academies, and academic spokespersons. Discussions focused on research priority setting as it is practiced within government organizations and suggestions on how the process might be improved. After considering this information, the Board finds that:

"A primary resource that would provide immediate benefits to decision makers is a broad-based, continuous capability for expert advice to both OMB and Congress during the budget allocation process."

- Federal priority setting for research occurs at three levels: 1) establishing Federal goals for research, 2) the budget allocation processes for research within the White House and the Congress that in the aggregate produce the Federal research portfolio and 3) Federal agencies and departments in achieving their missions and in accord with the President's priorities for research.

- The allocation of funds to national research goals is ultimately a political process that should be informed by the best scientific advice and data available.

- A strengthened process for research allocation decisions is needed. Such allocations are based now primarily on faith in future payoffs justified by past success, but are difficult to defend against alternative claims on the budget that promise concrete, more easily measured results and are supported by large and vocal constituencies.

- The pluralistic framework for Federal research is a positive aspect of the system and increases possibilities for funding high-risk, high-payoff research. An improved process for budget coordination and priority setting should build on strengths of the current system and focus on those weaknesses that can be addressed by improved data and broad-based scientific input representing scientific communities and interests across all sectors.

- There is a need for regular evaluation of Federal investments as a portfolio for success in achieving Federal goals for research, to identify areas of weakness in national infrastructure for S&T, and to identify a well-defined set of the top priorities for major new research investments.

- Additional resources are needed to provide both Congress and the Executive branch with data, analyses, and expert advice to inform their decisions on budget allocations for research.

Appropriate Scientific Advice

The scientific community can contribute to the Federal budget process as it now does within departments, agencies and programs, by providing:

- Reliable data and expert opinion on the most compelling major opportunities and needs for science and engineering, in the form of a well-defined set of top research priorities for substantial additional Federal investment;

- Effective processes for priority setting across fields of science and engineering, including multidisciplinary research and emerging areas;

- Estimated costs and benefits of various proposals, as well as overall funding levels, as input to decisions;

- Consensus across broad fields of research on the highest shared priorities for advancing Federal goals for science and technology—through mechanisms of Federal agency advisory bodies, expert scientific staff, the National Academies, and private and non-profit organizations of the research and education communities—to inform Federal allocation decisions.

At the Federal level, advice on priorities for major research facilities is an area for particular attention. Facilities costs must be estimated and include long-term commitments for operation and maintenance. In addition, consideration must be given to tradeoffs to enable funding for priority facilities.

Advice, analyses and data must be coordinated with the Executive branch and congressional budget processes if they are to be useful for informing research budget allocation decisions.

Improved Data and Analysis

Allocation decisions should be informed by available data and should employ a range of methods of analysis and data sources. Over the long term there is a need for improvements in data, methods, and analyses that track Federal funds and measure the costs and benefits of research. Needs include:

- Improved theoretical understanding of the relationship between publicly supported research and innovation;

- Improved measures of economic returns to research investments, as well as non-economic returns in improved quality of life;

- Improved understanding of the relationship between research investments and the S&T workforce;

- Broadly acceptable definitions of "research" especially at the field level—though admittedly difficult to establish—to enable unambiguous, self-consistent tracking of Federal funds and benefits across departments, agencies and sectors;

- Improved data for international comparisons, including both relative and absolute measures; and

- Improved databases and other tools for tracking research funds and measuring outputs.

Toward an Enhanced Process

The analytical and expert support available to inform research budget decisions need to be strengthened in both the Congress and the White House. A primary resource that would provide immediate benefits to decision makers is a broad-based, continuous capability for expert advice to both OMB and Congress during the budget allocation process. A longer-term need is the regular, systematic evaluation of the effectiveness of Federal investments in achieving Federal goals for research through OSTP, drawing broad-based input from scientific experts and organizations in all sectors. Complementing both are improved data and analysis on research opportunities and needs that trace Federal research investments through the budget process and beyond.

Strengthening the Federal mechanisms to inform research budget allocation decisions in the White House would add an important dimension to current mechanisms for scientific advice, which feature agency- and department-based external and internal scientific input as part of their budget deliberations. It would require additional resources in OSTP. Additional resources might also be needed to strengthen Congressional mechanisms to inform research budget decisions. Furthermore, investments in data systems and academic research on the relationship between publicly funded research and economic and social benefits would enable improvements in methods for measuring and estimating returns on public investments. The payoff would be a more effective system for allocating Federal research funds to contribute to national goals, and improved tools for measuring and communicating the benefits of Federal investments to policy makers and the general public.

IV. CONCLUSIONS AND RECOMMENDATIONS

Federally funded science and technology support the missions of every Federal department and agency and have enormous long-term impacts on the economy and the quality of life of American citizens. The growth in the national and global science and technology enterprise, the opportunities for discovery and innovation, and the changing Federal role in U.S. science and technology require the Federal Government to direct greater attention to assuring its investments in research produce the greatest benefits over the long term to the public.

A deliberate, scientifically grounded process is essential for identifying opportunities and needs for Federal research. Needs include human resources, instrumentation and facilities, alignment of the portfolio of Federal investments with national priorities for research, effective distribution of funding among research modes and performing organizations, closure of gaps in research resulting from changes in department and agency programs, and addressing patterns of under-investment in vital areas of fundamental research.

The Board finds that mechanisms that have evolved based on the legislation that established OSTP and on the cooperation between OSTP and OMB represent valuable progress toward a more coherent and sophisticated system to inform major decisions on Federal research investments. The OMB/OSTP/PCAST must be provided with additional resources to expand activities for managing Federal S&T as a portfolio, especially for ongoing evaluation of the effectiveness of Federal investments in achieving Federal goals for research. Additional complementary resources to provide timely expert advice, analyses and data to inform congressional budget allocation decisions are also needed.

KEYSTONE RECOMMENDATION 1

The Federal government, including the White House, Federal departments and agencies, and the Congress should cooperate in developing and supporting a more productive process for allocating and coordinating Federal research funding. The process must place a priority on investments in areas that advance important national goals, identify areas ready to benefit from greater investment, address long-term needs and opportunities for Federal missions and responsibilities, and ensure world class fundamental science and engineering capabilities across the frontiers of knowledge. It should incorporate input from the Federal departments and agencies, advisory mechanisms of the National Academies, scientific community organizations representing all sectors, and a global perspective on opportunities and needs for U.S. science and technology.

Research Community Input on Needs and Opportunities:

Steps can be taken in the short term to improve the information base for Federal research investments. A primary input to any process of priority setting for research is expert scientific advice on current and long-term opportunities and needs for research. Presently there is no widely accepted and broadly applied way for the Federal government to obtain systematic input from the science and engineering communities for making priority decisions about support for research and research infrastructure.

There is insufficient opportunity and capability within the framework of existing mechanisms for Federal research priority setting to undertake timely and broad-based assessments of the needs for Federal investments. A more effective system for managing the Federal research portfolio requires adequate funding, staffing and organizational continuity.

RECOMMENDATION 2

A process should be implemented that identifies priority needs and opportunities for research—encompassing all major areas of science and engineering--to inform Federal budget decisions. The process should include an evaluation of the current Federal portfolio for research in light of national goals, and draw on: systematic, independent expert advice from the external scientific communities; studies of the costs and benefits of research investments; and analyses of available data; and should include S&T priorities, advice, and analyses from Federal departments and agencies. The priorities identified would inform OMB in developing its guidance to Federal departments and agencies for the President's budget submission, and the Congress in the budget development and appropriations processes.

Executive Branch Advisory Mechanism:

The Executive branch should implement a more robust advisory mechanism, expanding on and enhancing current White House mechanisms for S&T budget coordination and priority setting in OSTP and OMB. Enhanced resources should include an adequate professional staff, perhaps on a rotating basis modeled on the Council of Economic Advisors. It is particularly essential that the advisory mechanism include participants who are experienced in making choices among excellent opportunities or needs for research. (For example, vice provosts for research in universities, active researchers with breadth of vision, and managers of major industrial research programs would be appropriate in this role.)

Evaluation criteria should reflect Federal goals for science and technology funding. The evaluation should consider the effectiveness of the broad portfolio of Federal support to science and technology for:

- sustaining and enhancing U.S. world leadership across the frontiers of knowledge;

- assuring the long-term vitality of the U.S. science and technology enterprise by investments in important areas and activities unlikely to be funded by other sectors;

- aligning human resources for science and technology with needs of the S&T workforce in the Federal and other sectors;

- serving Federal departmental and agency missions;

and should identify:

- a well-defined set of top research priorities where enhanced Federal investments could yield high payoffs to society; and

- potential tradeoffs to provide greater funding for priority activities.

RECOMMENDATION 2a

An Executive Branch process for ongoing evaluation of outcomes of the Federal portfolio for research in light of Federal goals for S&T should be implemented on a five-year cycle[14]. A report to the President and Congress should be prepared including a well-defined set of the highest long-term priorities for Federal research investments. These priorities should include new national initiatives, unique and paradigm shifting instrumentation and facilities, unintended and unanticipated shifts in support among areas of research resulting in gaps in support to important research domains, and emerging fields. The report should also include potential trade-offs to provide greater funding for priority activities. The report should be updated on an annual basis as part of the budget process, and should employ the best available data and analyses as well as expert input. Resources available to OSTP, OMB and PCAST should be bolstered to support this function.

Congressional Advisory Mechanism:

There is no coherent congressional mechanism for considering allocation decisions for research within the framework of the broad Federal research portfolio. The current system splits areas of research among numerous committees and subcommittees,

[14] The designation of a five-year cycle for evaluation of the Federal portfolio reflects both the size of the effort, which would require more than an annual process, and the rapid changes in science, which demand a frequent reevaluation of needs and opportunities for investments.

each considering a limited portion of the portfolio, making impossible consideration of impacts of budget allocation decisions on national science and technology capabilities. While the need for analytical resources for science and technology policy tailored to the congressional process has been growing, available resources have been eliminated or reduced in recent years. And though improvements in the White House process—particularly expansion of activities and resources available to OSTP—would benefit Congressional allocation decisions, one or more Congressional mechanisms to provide expert input to research allocation decisions are badly needed.

RECOMMENDATION 2b

Congress should develop appropriate mechanisms to provide it with independent expert S&T review, evaluation, and advice. These mechanisms should build on existing resources for budget and scientific analysis, such as the Congressional Budget Office, the Congressional Research Service, the Government Accounting Office, and the National Academies. A framework for considering the full Federal portfolio for science and technology might include hearings by the Budget Committees of both houses of Congress, or other such broadly based congressional forums.

Advice to Congress in developing its recommendations on Federal priorities and funding levels for research should make use of the best available data and analyses.

Definitions, Data and Data Systems:

In addition to an enhanced process for expert advice and assessment, there is a long-term need to improve tools—databases and analytic methods—for effective management of the Federal research portfolio.

High quality data and data systems to monitor Federal investments in research would enhance the decision process. Such systems must be based on definitions of research activities that are consistently applied across departments and agencies and measured to capture the changing character of research and research needs. Flexibility in defining categories of research for tracking purposes is especially important for monitoring emerging areas and addressing the range of modes for research—from the individual investigator to the major center or facility. Timely collection of data and ease of access are critical to be useful to the allocation decision process.

Improving data and data systems is a long-term objective but one that is necessary and increasingly urgent for managing the large, diverse Federal research portfolio to serve the Nation. It will require long-term commitment to improve data systems, with input from potential users and contributors, and appropriate support.

RECOMMENDATION 3

A strategy for addressing data needs should be developed. Such a strategy supported by OMB and Congress and managed through OSTP and OMB would assure commitment by departments, agencies and programs to timely, accessible data that are reliable across reporting units and relevant to the needs for monitoring and evaluating Federal investments in research. Current data and data systems tracking federally funded research should be evaluated for utility to the research budget allocation process and employed as appropriate.

International Comparisons:

Both relative and absolute international statistical data and assessments should be included as a major component of the information base to support Executive branch and Congressional research budget allocation decisions.[15] International benchmarking of U.S. research performance and capabilities on a regular basis responds to the growing globalization of science and technology and the need for the United States to maintain a world-class science and engineering infrastructure. Maintaining world-class capabilities enables the Nation to take advantage of opportunities for rapid advancements in knowledge in targeted areas of research and to capitalize on breakthroughs wherever they occur worldwide. Although international data and methods of analysis are limited, they should be employed with sensitivity to those limitations and with a long-term commitment to developing better methods and data for monitoring U.S. performance and strength in science and technology.

International comparisons should include a range of measures of national research resources and performance to produce objective assessments of the relative strength of the U.S. in research areas important to national goals. For example, comparisons could include total national S&T investment as a share of Gross Domestic Product (GDP) or as a share of the high technology sector of the economy. Relative performance of individual fields important to national economic or defense priorities can be assessed using bibliometric methods and patent citations. Comparisons should be sensitive to the appropriate basis for comparing different economies, since the composition of the economy may be as important as its size as measured by GDP. For example, it might not be appropriate to compare S&T/GDP ratios for two economies that have very different manufacturing shares of total GDP. Of central importance is the comparison of human resources for research in priority areas in the United States and in other countries, including international migration of science and engineering personnel as well as participation by U.S. students in science and engineering studies in comparison with students in other nations.

[15] National Science Foundation. Chapter 7, "Industry, Technology, and the Global Marketplace," in *Science and Engineering Indicators—2000* brings together a collection of indicators of national competitiveness.

Statistical trends are critical for evaluating the adequacy and direction of national research investments. Comparisons might include the following types of relative and absolute statistics:

- Total national S&T; Defense S&T; Civilian S&T; Basic (fundamental) research: National (U.S.) and Federal;
- Civilian S&T by functional categories of: health, energy, environment and natural resources, space research and technology, general science, transportation, agriculture;
- Basic science investment categories, such as: engineering, natural sciences, social science, and mathematical sciences; and
- Human resources engaged in or available for research by field, degree attainment, gender and nationality.

RECOMMENDATION 4

Input to Federal allocation decisions should include comparisons of U.S. research resources and performance with those of other countries. National resources and performance should be benchmarked to evaluate the health and vigor of U.S. science and engineering for a range of macroeconomic indicators, using both absolute and relative measures, the latter to control in part for the difference in size and composition of economies. Over the long term, data sources should be expanded and quality improved.

Federal Research Benefits to the Economy and Society:

In addition to monitoring Federal expenditures for research, measuring the benefits to the public of funded research is essential for prudent management. Although there is an extensive literature on methods for measuring returns on research investments, usually in the private sector, these methods have not been widely applied in the Federal context for a number of reasons. With regard to economic methods, the difficulties include lack of sufficient data, questions of data quality, selection bias in case studies of specific industries and problems of time lags between research discoveries and their impacts on the economy. In the case of publicly supported research, many benefits cannot be expressed in terms of economic returns. Indicators and methods that have been used for measuring benefits of research include the following:

- *Asset-oriented measures*, which tally such system "assets" as research facilities and human resources for S&T resulting from Federal investments—for example, immigrant and native-born scientists and engineers, and graduate students supported on Federal research grants;

- *Outputs measures,* which track intellectual contributions and often employ bibliometric analysis—such as patent citations, publication counts, article citations, presentations at conferences—or honors received by researchers and research projects, e.g. Nobel prizes;

- *Outcomes or results measures*, including: (1) case studies and retrospective analyses, which are usually qualitative, tracing the inputs and the processes that produced an important innovation and (2) quantitative economic techniques such as production function analyses and surveys estimating economic impacts of public research within specific industries and enabling a better understanding of the channels and mechanisms whereby public research contributes to innovation.

Implementation of this recommendation should be coordinated with Recommendation 3 on definitions and data systems.

RECOMMENDATION 5

The Federal Government should invest in the research necessary to build deep understanding and the intellectual infrastructure to analyze substantive effects on the economy and quality of life of Federal support for science and technology. The research should include improvements to methods for measuring returns on public investments in research.

Federal support for research has been highly successful in contributing to the quality of life that we enjoy in the United States today. Continued national commitment to publicly supported research offers the promise of even greater benefits in the future. The expanding frontiers of knowledge demand careful evaluation to identify the highest priorities for investment of Federal research funds. It is therefore essential that the processes by which allocation decisions are made rest on the best possible information base that high technology and well-prepared minds can produce. The systematic participation of the scientific community in this process along with Federal agencies and departments, bringing its vision and understanding of the needs and opportunities for research, is critical to its success. The Board's recommendations describe a strategy for improving the quality, content, and accessibility of science and engineering input to decisions on the allocation of Federal research funds. We are aware that implementing these recommendations will be difficult and will require long-term commitment. In the interest of science and the Nation, we urge that the Federal Government and its partners in the research community embrace this difficult task.

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CHAPTER I: INTRODUCTION

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CHAPTER II: NATIONAL POLICY CONCERNS AND NEEDS

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Box 7: Albert H. Teich. 1998. "An Introduction to R&D in the Federal Budget," in *Research & Development Report XXIII,* AAAS, Intersociety Working Group, p. 14.

FIGURES

CHAPTER I: INTRODUCTION

Figure 1: U. S. R&D/GDP 1953-2000.
Source: National Science Foundation/Division of Science Resources Studies, *National Patterns of R&D Resources* (annual series).

CHAPTER II: NATIONAL POLICY CONCERNS AND NEEDS

Figure 2: Shares of National R&D Funding by Source: 1953-2000
Source: National Science Foundation/Division of Science Resources Studies, *National Patterns of R&D Resources* (annual series).

Figure 3: Shares of Federal Research by Field
Source: National Science Foundation/Division of Science Resources Studies, *Survey of Federal Funds for Research and Development: Fiscal Years 1999, 2000, and 2001.*

ACRONYMS

AAAS	American Association for the Advancement of Science
AAU	Association of American Universities
AWIS	Association for Women in Science
BMBF	Germany, Federal Ministry of Education and Research
CA	California
CEA	Council of Economic Advisors
CEO	Chief Executive Officer
CBO	Congressional Budget Office
CNRS	Centre National de la Recherche Scientifique
COSEPUP	Committee of Science, Engineering and Public Policy
CRA	Computing Research Association
CRS	Congressional Research Service
DDR&E	Director of Defense Research and Evaluation
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DTI	Department of Trade and Industry, UK
EC	European Commission
EPA	Environmental Protection Agency
EU	European Union
FCCSET	Federal Coordinating Council on Science and Technology
FY	Fiscal Year
GDP	Gross Domestic Product
GPRA	Government Performance and Results Act
HHS	Health and Human Services (Department of)
HMSO	Science Office, UK
HUD	Housing and Urban Development, Department of
IDEA	Indicators and Data for European Analysis
IRI	Industrial Research Institute
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration
NCRR	National Center for Research Resources, NIH
NIH	National Institutes of Health
NIST	National Institute for Standards and Technology
NOAA	National Oceanographic and Atmospheric Administration
NAE	National Academy of Engineering
NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council (OSTP)
MIT	Massachusetts Institute of Technology
OMB	Office of Management and Budget
OECD	Organization for Economic Cooperation and Development
OST	Office of Science and Technology, UK
OSTP	Office of Science and Technology Policy
PCAST	President's Council of Advisors on Science and Technology
PL	Public Law

R&D	research and development
RTD	Research and Technological Development Policy (EU)
RaDiUS	Database System of Research and Development in the U. S.
S&T	Science and Technology
SPI	Strategic Science and Engineering Policy Issues committee
SPRU	Science Policy Research Unit, Sussex
STPI	Science and Technology Policy Institute, RAND
UK	United Kingdom
USDA	U.S. Department of Agriculture
VA	Department of Veterans Affairs

APPENDICES

APPENDIX A

NSB –99-56
3/23/99

CHARGE

NATIONAL SCIENCE BOARD
AD HOC COMMITTEE ON STRATEGIC
SCIENCE AND ENGINEERING POLICY ISSUES

The NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues is hereby reconstituted to lead a study of methodologies for coordination and priority setting in the development of the Federal budget for science and engineering research.

In its Working Paper on *Government Funding of Scientific Research* (NSB-97-186), the National Science Board identified a national interest in "some form of 'comprehensive' and 'coherent' coordination of Federally-financed research," which would first require the development of "guidelines to provide clear direction on setting priorities within the Federal research budget." The recently adopted Strategic Plan of the National Science Board states that: "...the development of an intellectually well founded and broadly accepted methodology for setting priorities across fields of science and engineering is a prerequisite for a coherent and comprehensive Federal allocation process for research."

Since publication of that paper at the end of 1997, stakeholders in both the Administration and the Congress have urged better coordination for the Federal budget for research, and the development of a methodology for priority setting across fields of science and agencies to further that objective. Specifically, in its report accompanying the NSF Appropriations Act for FY 1999, the House Committee on Appropriations stated its strong agreement with the NSB report and urged the Board to "...develop the guidelines for such a study and provide for the committee at the earliest possible date a proposed plan...to accomplish this task and institute such a study."

The committee will:

- Review, in light of changing circumstances, the goals for Federal investment in scientific research as stated in the Administration report, Science in the National Interest;
- Examine existing structures and processes for coordination and priority setting for Federally-funded research across the Federal government and the role played by individual agencies in this process;
- Conduct a state of the art assessment of methodologies that inform priority setting for research;

- Conduct a study of budget coordination and priority setting for research as it is practiced in other countries to understand their particular advantages or disadvantages; and
- Convene appropriate stakeholders to consider the findings of these studies and reviews, to develop recommendations for improved methodologies for coordination and priority setting in the Federal research budget and for building the support of the science and engineering communities and of the general public in these methodologies.

The committee may employ a variety of mechanisms to accomplish these objectives, including consultants and independent studies, briefings, workshops, conferences, and forums. The committee may consider recommending to the National Science Board the establishment of an NSB Commission for the development of final recommendations on methodologies for coordination and priority setting. An interim report on findings on the current state of the art and next steps to be submitted to the Board in March 2000, and the final report and recommendations no later than December 2000.

Eamon M. Kelly
Chairman

APPENDIX B: PRESENTATIONS AND DISCUSSION WITH COMMITTEE

The NSB Ad Hoc Committee on Strategic Science and Engineering Policy Issues heard presentations by invited experts, addressing the following methodologies and methodological issues:

1. A project to develop a more complete and accessible database for tracking Federal R&D funding, the RaDiUS database, undertaken by the RAND Science and Technology Policy Institute (STPI), and the potential of the database for use as a tool for budget coordination and priority setting across areas of research and government programs, presented by STPI Director Bruce Don and Donna Fossum, May 5, 1999;

2. Foresight methods, used by many countries as part of the dialogue toward establishing priorities for S&T, by an expert on Foresight methods in use in Organization for Economic Co-operation and Development (OECD) countries, Mary Ellen Mogee, July 28, 1999;

3. The Federal Science and Technology (FS&T) budget analysis by the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academies and the American Association for the Advancements of Science (AAAS), by James Duderstadt speaking for COSEPUP, March 15, 2000;

4. Experiments in international benchmarking of U.S. research fields, sponsored by the National Academies, by Maxine Singer and Marye Anne Fox for COSEPUP, May 3, 2000;

5. Approaches to priority setting for research in the academic sector, and the relationship between Federal and academic priority setting, by the Chairman of the Social, Behavioral and Economic Sciences Directorate Advisory Committee, Irwin Feller, July 28, 1999;

6. Priority setting practices in industry that might be useful in improving Federal priority setting, and the role of industry and the Federal Government in national R&D by Charles Larson, President of the Industrial Research Institute, March 15, 2000;

7. A meeting with experts on the Federal budget and economic methods to measure the benefits of Federal investments in research, October 20, 2000. (Agenda in Appendix C)

Meetings with participants in the current Federal system include:

1. An all-day meeting August 4, 2000, with presentations on priority setting from 10 Federal S&T agencies, Office of Science and Technology Policy, by Director Neal Lane, Office of Management and Budget by Kathleen Peroff (Agenda in Appendix C);

2. OMB staff members, including the Steven Isakowitz, Chief, Energy and Science Division and Program Examiners David Radzanowski, Sarah Horrigan and David Trinkle, who reviewed and discussed the Committee's initial draft recommendations, August 2, 2000;

3. House Appropriations Chief of Staff Frank Cushing, December 13, 2000.

4. A stakeholders symposium on Allocation of Federal Resources for Science and Technology, May 21-22, 2001, with 20 panelists and speakers, and more than 200 attendees from Federal agencies, Congressional staff, OMB staff, scientific professional organizations, policy organizations, the National Academies, and OSTP staff, as well as interested individuals. (Agenda in Appendix C).

In these meetings the Committee discussed with Federal colleagues the current structure and process for budget coordination and priority setting in the Federal government and thoughts on how the process might be improved.

Finally, a one-and- a- half day symposium on *International Models of S&T Budget Coordination and Priority Setting*, November 19-20, 1999, with presentations by foreign officials intimately involved in S&T budget coordination and priority setting from eight governments was cosponsored by the SPI Committee and Task Force on International Issues in Science and Engineering. Governments represented included: the UK, Germany, France, Sweden, the Republic of Korea, Japan, Brazil, the European Union and the United States. (Agenda in Appendix C).

APPENDIX C

Agendas and Guidelines for
Selected Stakeholder and Expert Meetings

NSB/SPI 00-40

AGENDA

Symposium on

Allocation of Federal Resources for Science and Technology

National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230
Room 375

Monday, May 21

2:00-2:20 Introduction and Overview: Eamon Kelly, NSB Chairman

2:20-2:30 Welcome: Rita Colwell, NSF Director

2:30-3:00 Keynote Address: Newt Gingrich, U.S. Commission on National Security/21st Century and Former Speaker of the House: *The Role of Federal Research in the Nation's Prosperity and Security*

Break

3:10-5:30 The Case for a Better Process

Moderator: Joseph Miller, NSB member

- OMB Perspective: Kathleen Peroff, Deputy Associate Director for National Security
- Congressional perspective: Scott Giles, Deputy Chief of Staff, House Committee on Science
- Research funders and performers: Erich Bloch, Washington Advisory Group, Former Director, NSF
- Higher Education: Donald Langenberg, Chancellor, University System of Maryland

5:30-6:15 Discussion

6:15-7:15 *Reception (by invitation): National Science Board Suite, Room 1225*

Tuesday, May 22

8:30-8:45 Welcome and Introduction: Eamon Kelly, NSB Chair

8:45-10:45 Improving the Budget Process for S&T

Moderator: John Armstrong, NSB member

- Lead: Lewis Branscomb, American Association for the Advancement of Science/Kennedy School of Government, Harvard University
- American Enterprise Institute: Claude Barfield
- Budget Support for the White House and Congress:
  - OMB: Steven Isakowitz, Branch Chief
  - Senate: Cheh Kim, Senate staff
- National Academies: James Duderstadt, University of Michigan

Break

11:00-12:00 Discussion

12:00-1:00 *Lunch (by Invitation): Board Suite, Room 1225*

1:00-3:00 Evaluating and Identifying Priorities for Federal Research: The Role of the Science and Engineering Communities

Moderator: Robert Richardson, NSB Member

- Lead: Senior researcher: Paul Romer, Stanford University
- Disciplinary communities
  - Astronomy and Astrophysics: Joseph Taylor, Princeton University
  - Computing Research Association (CRA): Andries van Dam, Brown University
  - Federation of American Societies for Experimental Biology (FASEB): John Suttie, Past President
  - Environmental Research: Kenneth Brink, Woods Hole Oceanographic Institution, Chair, Ocean Studies Board, NAS
- Industry research: Henry Weinberg, Symyx Technologies, Inc., Chief Technology Officer
- Higher education: Nils Hasselmo, President, Association of American Universities

3:00-3:45 Discussion

Break

4:00-5:45 Better Data and Analyses

Moderator: Eamon M. Kelly, NSB Chairman

- Lead: Albert Teich, AAAS
- Agencies/Departmental Role:
  - o NSF: Rita Colwell, Director
  - o DOE: James Decker, Acting Director, Office of Science
- NIH: Yvonne T. Maddox, Acting Deputy Directoro
- DoD: Delores Etter, Acting Director, DDR&E

5:45-6:30 Discussion/Concluding remarks

6:30 Adjourn

EXAMPLE LETTER TO SPEAKERS AND PANELISTS

April 25, 2001

Dear:

I am writing to invite you to participate in the upcoming National Science Board symposium on the Allocation of Federal Resources for Science and Technology, May 21-22. Enclosed is the draft discussion paper*, The Scientific Allocation of Scientific Resources*, that lays out our preliminary recommendations on improving the expert advice and data to inform Federal research budget allocation decisions, which will serve as the focus of the symposium. I hope you will be able to participate in a panel discussion on May 2X, emphasizing on our recommendation(s) on (one or more specific recommendations in the discussion document) representing the perspective of (sector, organization, or community).

By way of background, over the last two years the Board has undertaken a study of methodologies and criteria to set priorities for Federal research funding across scientific fields and, further, to define a process that would be effective in building broad public and scientific community support for, and involvement in, priority setting for federally supported research. Our study has addressed priority setting practices for publicly funded research, both in the U.S. and in other countries.

We have commissioned two literature reviews, one by the RAND Science and Technology Policy Institute on Federal support for research, the existing tools to support research budget allocation decisions, and current mechanisms for input on those decisions. The second study, by SRI International, examined the literature on international models of S&T budget coordination and priority setting, focusing on eight foreign governments, with presentations by top-ranking science officials for each. We also heard presentations from experts on specific methodologies proposed or in use to assist priority setting in research budgets.

The Strategic Science and Engineering Policy Issues committee, which is undertaking this study for the Board, has met with representatives of the Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), the National Academies, and Congressional staff who expressed considerable interest in improving the process by which funding decisions are made for federally supported research. The committee has arrived at some preliminary conclusions from these sources and, as part of our study, begun a dialog with policy officials most intimately involved in the budget process in the Federal research funding agencies.

Enclosed is a copy of a preliminary agenda for the event. We would ask that you and other panel members take a few minutes at the beginning of the panel discussion to outline your reactions

and thoughts on the report, focusing on recommendation(s)___, followed by a discussion with other members of the panel. A more general discussion including NSB members and others in the audience will follow.

This panel is scheduled to begin at_____ on _____, May 2X. I have asked the National Science Board office to contact you concerning your availability for this event.

I hope you will be able to join us and contribute to this important discussion.

Sincerely,

Eamon M. Kelly, Chairman
National Science Board
Chairman, Committee on Strategic
Science and Engineering Policy Issues

Enclosures

NSB/SPI 00-20
Revised 10/20/2000

AGENDA
NSB Ad Hoc Committee on
Strategic Science and Engineering Policy Issues
October 20, 2000

8:30-8:45 Introductory remarks, Dr. Eamon Kelly, NSB Chairman

8:45-10:45 *Setting Priorities for Federal Research: Economists' Perspectives on the Federal Budget Process*
Moderator: Dr. Eamon Kelly, NSB Chairman
(1) June O'Neill, Baruch College, Former Director, CBO
(2) Kathryn Shaw, Council of Economic Advisors

10:45-11:00 Break

11:00-12:30 *Social and Private Returns on Investment in Federally-funded Research*
Moderator: Dr. Joseph Miller, NSB
(1) Wesley Cohen, Carnegie-Mellon (by video)
(2) Paul Romer, Hoover Institution, Stanford (by video)

12:30-1:00 Lunch

1:00-2:00 *Committee Discussion*

NSB/SPI 00-14
Revised 8/2/2000

Draft Agenda
NSB Committee on Strategic Science and Engineering Policy Issues
Meeting with Federal Agencies on the
Federal R&D Budget Allocation Process
National Science Foundation
August 3-4, 2000

August 3 **Room 1225, Board Suite**

6:00-7:30 Reception, NSB, DPG and Agency guests

August 4 Room 1225, Board Room

8:30-8:45 Introduction by E. Kelly, Chairman, Strategic Policy Issues Committee

8:45-9:15 Remarks by Dr. Neal Lane, Assistant to the President for Science and Technology

9:15-10:00 Dr. Bruce Don, Science & Technology Policy Institute, RAND, "Setting Priorities and Coordinating Federal R&D Across Fields of Science"

Comment from OMB, Kathleen Peroff, Deputy Associate Director for Energy & Science

10:00-10:15 *Break*

10:15-12:15 **Major civilian research agencies: Anita Jones, NSB**

- Dr. Ernest Moniz, Under Secretary, DOE
- Dr. Mildred Dresselhaus, Director, Office of Science, DOE
- Dr. Ruth Kirschstein, Acting Director, NIH (HHS)
- Dr. Rita Colwell, NSF Director
- Dr. Kathie L. Olsen, Chief Scientist, NASA

12:15-12:45 Discussion

12:45-1:45 *Lunch*

1:45-2:45 **Major defense research agencies: John Armstrong, NSB**

- Robert V. Tuohy, Director, S&T Plans and Programs, DOD
- Dr. David Crandall, Assistant Deputy Administrator for Research, Development and Simulation, DOE

2:45-3:15 Discussion

3:15-3:30 *Break*

3:30-4:45 **Civilian agencies funding natural resources and environmental R&D: Joseph Miller, NSB**

- Dr. Floyd P. Horn, Administrator, Agricultural Research Service
- Dr. Norine Noonan, Asst. Administrator for R&D, EPA
- Dr. Ronald Baird, Director, National Sea Grant College, NOAA (DOC)

4:45-5:15 **Other civilian research programs: Robert Richardson, NSB**

- Dr. John R. Feussner, Chief R&D Officer, VA
- Dr. Michael Casassa, Acting Director of the Program Office, NIST (DOC)

5:15-5:45 Discussion, concluding remarks

NSB/SPI-99-11
REVISED 11/17/99

AGENDA
SYMPOSIUM ON INTERNATIONAL MODELS
FOR S&T BUDGET COORDINATION AND PRIORITY SETTING
November 19-20, 1999

Co-sponsored by the National Science Board
Committee on Strategic Science and Engineering
Policy Issues and
Task Force on International Issues in Science and Engineering

Thursday, November 18

6:00 pm *Reception/Dinner* (*by invitation*)*;* Guest Speaker: Neal Lane, Science Adviser to the President, Room 375, National Science Foundation

Friday
Boardroom, Room 1235

1. 8:30-9:00 Opening remarks: Eamon Kelly, NSB; Chairman, Diana Natalicio, NSB Vice Chair
   Welcome: Rita Colwell, NSF Director

2. 9:00-1:00 *Models of Change in Industrialized Countries*

   Moderator, Dr. Joseph Miller, NSB

   -**Germany**: Bernd Kramer, Science Counselor, German Embassy

   -**France:** Jacques Sevin, Director of Strategy and Programs, Centre National de la Recherche Scientifique (CNRS)

   Break

   -**Japan**: Tsuyoshi Maruyama, Director of Planning and Evaluation Division, Science and Technology Policy Bureau, Science and Technology Agency

Summary and Discussion

1:00-2:00 *Lunch break*

3. 2:00-5:15 *Models with Established Central Mechanisms*

Moderator: Dr. Anita Jones, NSB

-**European Union**: Graham Stroud, assistant to the Deputy Director, Research Directorate General, European Commission

Break

-**United Kingdom**: Jo Durning, Group Head of Transdepartmental Science and Technology, Office of Science and Technology (OST)

Summary and Discussion

Reception 5:30-7:00, Board Suite, room 1225

Saturday

4. 8:30-11:00 *Models of Change in Smaller R&D Systems*

Moderator: Dr. Pamela Ferguson

-**Korea**: Heeseung Yang, Managing Director, National Research and Development (R&D) Evaluation, Korea Institute of Science and Technology Evaluation and Planning

-**Sweden**: Kerstin Eliasson, Director, Research Policy Directorate, Ministry of Education and Science

-**Brazil**: Luiz Antonio Barreto de Castro, Head of the Secretariat of Intellectual Property Rights, Empresa Brasileira de Pesquisa Agropecuaria – Embrapa

Break

5. 11:00-12:00 *Summary and Discussion*

I. Background and Objective of the Symposium

In its Working paper on *Government Funding of Scientific Research* (NSB-97-186), the National Science Board identified a national interest in "some form of 'comprehensive' and 'coherent' coordination of Federally-financed research," which would first require the development of "guidelines to provide clear direction on setting priorities within the Federal research budget." The Strategic Plan of the National Science Board states that: "...the development of an intellectually well founded and broadly accepted methodology for setting priorities across fields of science and engineering is a prerequisite for a coherent and comprehensive Federal allocation process for research." In recent years, stakeholders in both the Administration and the Congress have urged better coordination for the Federal budget for research, and the development of a methodology for priority setting across fields of science and agencies to further that objective.

As a consequence, the *Ad Hoc* Committee on Strategic Science and Engineering Policy Issues, acting in concert with the NSB Task Force on International Issues in Science and Engineering, undertook the arrangement of a "Symposium on International Models for S&T Budget Coordination and Priority Setting. The objective of the Symposium and its background preparations was to provide a review of the relevant literature, as well as hearing the views of a number of active R&D policy makers across a variety of internationally representative countries. The Symposium was held on November 19-20, 1999, in the NSF Board Room, where Committee and Task Force members heard presentations and engaged in dialogue with representatives of seven countries and one international entity, the European Union, on the topic. The participating countries were selected on the basis of the following criteria:

- Does the country have sufficient experience to serve as a model?
- Does the methodology or aspects of it have potential for application to the U.S.?
- Is the methodology sufficiently different from others to offer special lessons?
- Does inclusion of the country need to be considered for political or representational reasons?
- Are excellent presenters/spokespersons for the country's system likely to be available?
- Does the system for government support of research appear to contribute positively to the scientific and engineering strength of the country?

The countries selected for participation included three large European nations – France, Germany, and the United Kingdom, as well as the European Union, which is a major sponsor of research. Two other industrialized nations, Japan, a major Asian industrial nation, and Sweden, a smaller but scientifically highly advanced country were included. One "Newly Industrialized Economy," the Republic of Korea, and Brazil, the largest scientific presence in Latin America, filled out the roster of participants.

SRI International, a contractor, was asked to identify as potential speakers individuals with roles like that of the U.S. science advisor: in government; intimately knowledgeable about how the process works; and at a high level. Normally that would not be the minister of science or equivalent, who are often in office very briefly and who cannot speak from extensive experience about their government's funding for R&D. Countries vary, but the individuals invited were all at a high level in government and very knowledgeable about how the research budget is actually developed.

The following framework for presentations was provided to the invited guests of the National Science Board:

Guidelines for Speakers

Your presentation should be limited to approximately 25 minutes, followed by a question and answer period with members of the Committee and the Task Force.

Board members will have received a briefing document on your country's R&D budget process prior to the Symposium, outlining the general structure and procedures for your national system as they are described in the published literature. We will be supplying you with a copy of that background document. We ask, therefore, that you assume that Board members are familiar with the background material and address your presentation to the following questions, as appropriate to your national system.

Questions to Address on R&D Budget Co-Ordination and Priority Setting

Q1: What needs are targeted in your country's R&D budget--government, industry, society as a whole? International cooperative R&D for activities such as megascience projects, major instrumentation, databases, or human resource capacity building?

Q2: In planning for your government's budget for R&D, how are appropriate levels of support determined for the budget as a whole and for programs and activities funded through the R&D budget?

Q3: Are the research activities of other countries a significant factor in developing your R&D budget? How do you evaluate research supported by other countries? Which other countries? How is this information used in your budgeting activities?

Q4: Please describe the priority setting process in detail.

- What are the key organizations or individuals involved in the priority setting process for the R&D budget? What measures or indicators, models or methodologies are employed in weighing alternative prospects for government investments in R&D?
- How is the priority setting process applied to government support for ***fundamental*** research?

Q5: How do you determine that an area is worth pursuing as a national priority, or whether it should be left to other countries? How do you decide which areas should be pursued collaboratively?

- Do multinational themes, e.g. in the environment, enter into the process for determining national priorities for R&D?
- How are international collaborations supported: direct funding, in-kind contributions, other means?
- Does your government make any specific or special provisions for scientific cooperation with developing countries? If so, are these handled out of your science ministry or equivalent or some other part of the government?

Q6: What mechanisms and tools do you use to assess the benefits of scientific research and development and its contributions to your society?

- What units of analysis are used in measuring the return on government investment? e.g., government agencies and their programs; nongovernmental organizations or sectors that receive government support, such as universities or research institutes; scientific fields of study/disciplines; industrial research and technologies; occupational groups; geographic/political units?

Q7: What data are available for measuring R&D investments and returns on your country's investments? Are these sources available in published or electronic form?

APPENDIX D: WRITTEN COMMENTS ON THE BOARD'S DRAFT DISCUSSION DOCUMENT, *THE SCIENTIFIC ALLOCATION OF SCIENTIFIC RESOURCES* (NSB-01-39)

Organizations:

American Institute of Physics: Mark H. Brodsky, Executive Director and CEO

American Psychological Association Raymond: C. Fowler, Chief Executive Officer and Norine Johnson, President

Association of Women in Science (AWIS): Linda Mantel, President, and Catherine Didion, Executive Director

Council of Scientific Society Presidents: Martin Apple, Ph.D., President,

Federal Aviation Administration, Dr. Aston McLaughlin

McGeary and Smith: Michael McGeary and Phil Smith

National Academy of Engineering (NAE): Lance Davis, Executive Officer, reported three responses from individual members

Alfred P. Sloan Foundation: Ralph Gomory, President

U.S. Commission on National Security/21st Century: Adam Garfinkle

University of California: C. Judson King, Provost and Senior Vice President, Academic Affairs

Individuals:

Lewis Branscomb, Harvard University (also symposium panelist)

George Brimhall, Department of Geology and Geophysics, University of California, Berkeley, CA

Harry Cook

George Dacey

Professor Earl H. Dowell, Dept. of Mechanical Engineering and Materials Science, School of Engineering, Duke University, in response to NAE notice requesting comment

Rebecca Dresser, JD, Professor of Law and Ethics in Medicine, Washington University, St. Louis

Thomas W. Eagar, Materials Science and Engineering, MIT

Albert Henderson, Publishing Research Quarterly

John D. Holmfeld

Jeff Ullman, Stanford University, Computing Science? in response to NAE request for comment

Professor Richard Zare, Stanford University

APPENDIX E

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